Age of the Universe:

10 - 25 Billion Years

COSMIC TIMES

1965

Size of the Universe:

25 Billion Light Years

MURMUR OF A BANG

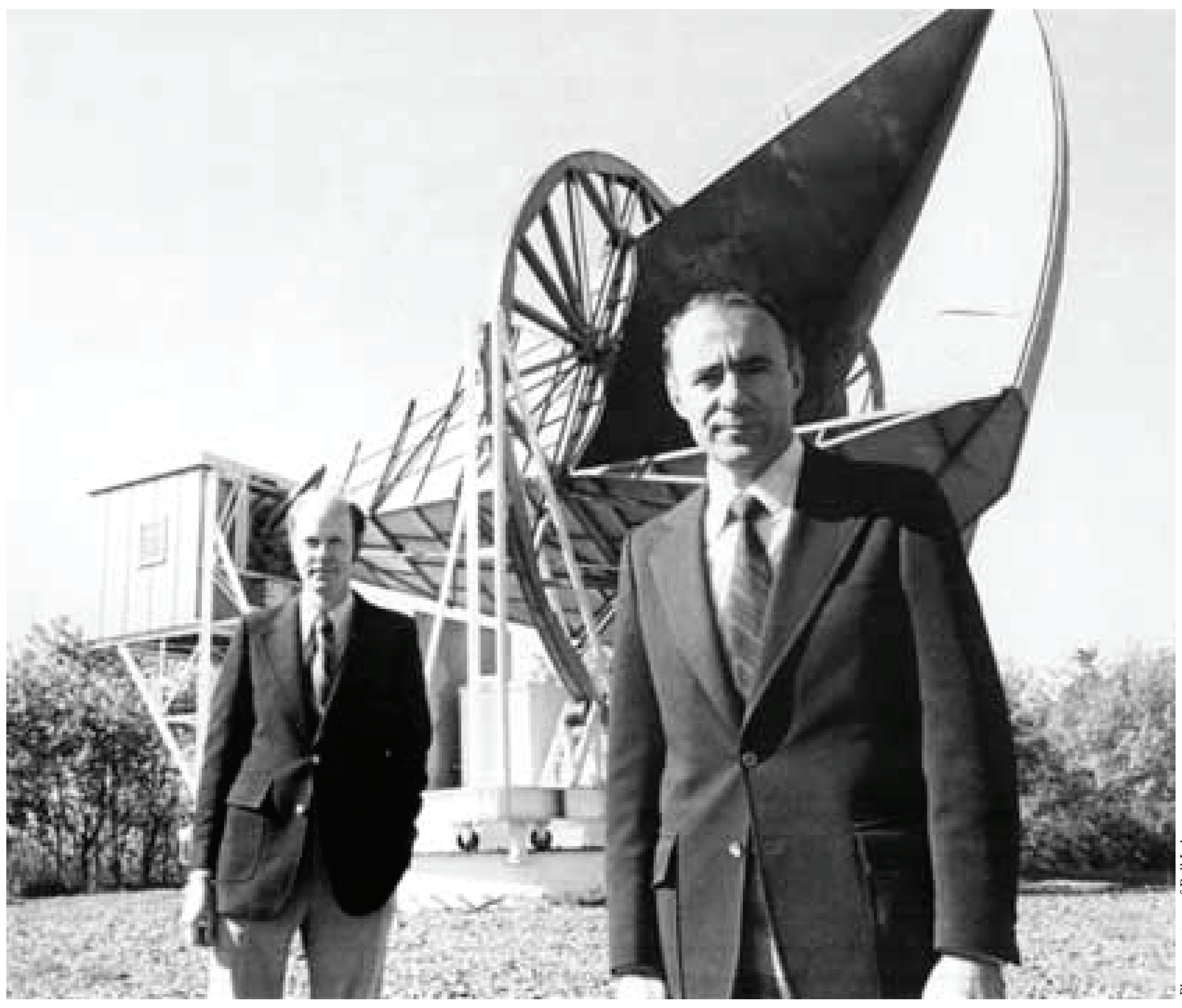


Photo courtesy of Bell Labs

Robert Wilson (left) and Arno Penzias stand in front of their horn reflector antenna in Holmdel, New Jersey. They discovered a radiation signal that matches that expected by theorists who proposed that the universe began with a hot explosion called the "big bang". This discovery was made by accident as they tried to track down the source of unwanted noise in their receiver.

Astronomers have identified a faint cosmic radio rumble as the distant roar of the universe's birth. The discovery not only provides the first observational evidence that the universe started with a "big bang," but it also has implications for how it might end.

The faint radio hiss comes in the form of 7.3-centimeter microwaves, which lie on the electromagnetic spectrum between radio waves and infrared light. The microwaves come from every direction in space, without regard to time of day or season. The background radiation signal matches that expected by some theorists who proposed that the universe began with a hot explosion of hydrogen about seven billion years ago and has been cooling ever since.

The discovery of what's being called "cosmic black body radiation," where the wavelength of radiation emitted is directly related to the temperature, was made more or less by accident by Arno Penzias and Robert Wilson of Bell Telephone Laboratories. The two were trying to track down the source of unwanted radio noise in the 20-foot horn reflector antenna at the Crawford Hill Laboratory in Holmdel, N.J. The "Holmdel horn" antenna was built to test telecommunications with the Echo satellite.

When the Holmdel horn was aimed at zenith, Penzias and Wilson found that it picked up the 7.3-centimeter microwave signal consistent with a temperature of 6.7 degrees Kelvin. That is to say, it corresponded to 6.7 degrees above the theoretical value of absolute zero, at which there is no thermal energy at all. After subtracting natural microwave energy emissions from Earth's atmosphere and energy losses in the antenna itself, Penzias and Wilson were left with an unexplained temperature of about 3.5 degrees Kelvin, give or take one degree, coming from empty space.

Luckily, just down the road some Princeton scientists had the solution. Astronomer Robert Dicke and his team were in the process of building a radio telescope for the express purpose of finding the whisper of the Big Bang. When they heard about Penzias' and Wilson's mystery microwave hiss, they knew it was their prey. After conferring, the Bell Lab and Princeton teams announced the discovery in a pair of letters published in the July issue of Astrophysical Journal.

"The presence of thermal radiation remaining from the fireball is to be expected if we can trace the expansion of the universe back to a time when the temperature was of the order of ten billion degrees Kelvin," wrote Dicke and his colleagues. This, they conclude, was the time when the universe began with a Big Bang from a very hot, dense ball of primordial matter and energy.

Stunning and significant as the discovery is, to some astronomers it wasn't a surprise. Theorists including George Gamow, Ralph Alpher and Robert Herman had argued in the late 1940s for a Big Bang and that its remnant heat ought to be still detectable. In 1949, Alpher and Herman reworked some of Gamow's earlier calculations and actually predicted that the remaining radiation would now have a temperature of "a few degrees Kelvin." The new observations of this background radiation support their prediction.

Where Alpher and Herman went wrong, however, is in thinking that the dying thunder of the Big Bang would be drowned out by today's starlight, cosmic ray particles, and the other noisy emissions of an active universe. Instead, it appears that the remnants of the Big Bang have cooled in a way that channels energy into specific bandwidths. This is what Dicke and his team suspected and one reason they were planning to look in the microwave realm. It's also how they knew Penzias' and Wilson's excess microwave noise was a significant discovery.

The discovery of this cosmic black body radiation has driven more nails into the coffin of the "steady-state" universe theory, favored by many astronomers not long ago. Steady-state theory holds that the eternal expansion of the universe is spurred on by the spontaneous creation of particles in empty space. Such a theory does not predict the cosmic black body radiation, making it incompatible with the new data.

The Big Bang implies a range of possible fates for the universe. It will either expand and cool forever as an "open universe," according to Dicke and his team, or it is a "closed universe."

In a closed universe the gravity of all the matter in the universe will pull it back together into another hot ball, breaking down matter and energy into their basic building blocks. Then it will explode again into another, totally new universe. Dicke refers to this version of a closed universe as an "oscillating universe." This option resembles the steady-state model in at least one respect: it has no ultimate beginning or end. Sadly, however, it offers no way of detecting what came before the last bang and no escape from being crushed together into another hot ball before the next.

Big Hiss Missed By Others

One of the biggest surprises from the recent discovery of the Big Bang's faded thunder is how many times others have missed it.

Just last year, Russians Andrei Doroshkevic and Igor Novikov published a study that calculated correctly that, if the Big Bang happened, the remnant heat would now be between 1 and 10 degrees Kelvin. They even proposed searching for the signal in sky temperature measurements made by Edward Ohm in 1961.

Ironically, Ohm had gathered that data using the same Holmdel horn antenna used by Arno Penzias and Robert Wilson this year at Bell Laboratories to identify the 3.5 degrees Kelvin background radiation of the Big Bang. But Ohm found a 3.3 degrees Kelvin noise that he assumed was coming from the antenna itself. The Bell Laboratories team has been able to say with far more confidence that the faint excess static truly came from space, because they had to weed out the antenna's own noise to arrive at their conclusions.

There were two other near misses as well. Ten years ago Émile Le Roux reported a background radiation of 3 degrees Kelvin, plus or minus 2 degrees, while studying the sky in the 33-centimeter radio wavelength at Paris' Nançay Radio Observatory. In 1957, Russian Tigran Shmaonov nearly made the discovery, reporting that he measured a background temperature of 4 degrees Kelvin, give or take 3 degrees, while looking at the 3.2-centimeter wavelength of microwaves.

The missing piece in both Le Roux's and Shmaonov's work was the connection of what they had seen, to theoretical predictions from the Big Bang made as early as 1948. It was a matter of having the right data, without a theory to make sense of them. Penzias and Wilson would have fared no better had not their neighbors at Princeton helped them recognize the noise as the long-sought remnant radiation.

Galaxies Still Misbehaving

Recent attempts to weigh galaxies still come up a bit short. Two spiral galaxies under study, NGC 3521 and NGC 972, have weighed in at 80 billion and 12 billion suns, respectively. The puzzle is why the amount of starlight from these galaxies doesn't add up to such huge amounts of matter.

The starlight measurements of the two galaxies are based on careful accounting of the galaxies' total luminosity, or magnitude, as recorded on photographic plates. It also takes into account the way the galaxies' stars are arranged from their centers to the edges.

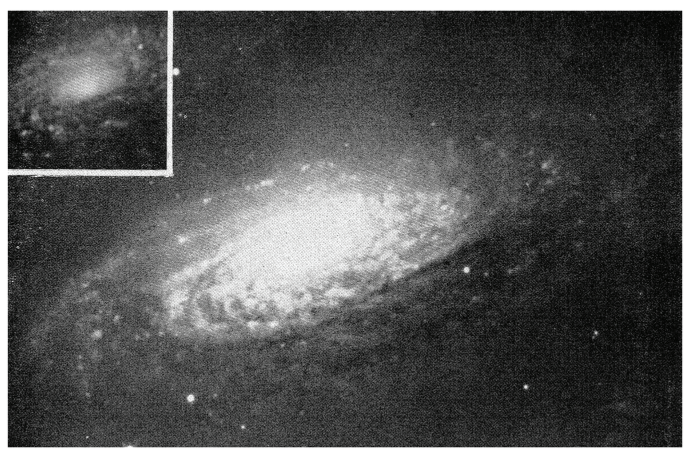
The mass measurement is based on the same idea that long ago allowed astronomers to calculate the mass of the Sun: if a relatively small-mass object orbits a very large-mass object at a known speed, the larger object's mass can be determined mathematically. The same physics applies to stars orbiting a galaxy's center of gravity.

Since the motions of the extremely distant stars are not detectable through any telescope, researchers sampled slivers of galactic starlight from different parts of the galaxies and split the light into spectra – their rainbows of color. These spectra contain patterns of lines, representing different energies, that shift in proportion to the speeds of the stars.

To make comparisons easier, astronomers blend luminosity and mass measurements into a single number called a mass-to-light ratio. Our Sun, for example, has a mass-to-light ratio of one "solar mass" divided by one solar luminosity, which equals 1. A ratio greater than 1 implies more mass than luminosity – which means that some mass is not accounted for.

In the case of NGC 3521, measurements from the University of Texas' powerful 82-inch telescope at McDonald Observatory give it a mass-to-light ratio of 4 or greater. NGC 972 is a bit less worrisome, with a ratio of 1.2. These results were reported in recent issues of Astrophysical Journal by teams of researchers led by Margaret Burbidge of the University of California at San Diego. Other researchers are finding similar mismatches in galaxies everywhere, and no one has yet offered a comfortable explanation.

About the only consolation galactic weight watchers may have is that their missing matter problem is far less extreme than that of Caltech astronomer Fritz Zwicky. In 1933, he pioneered similar measurements, though on a grander scale. Assuming that all the mass in a galaxy contributes to its brightness, he calculated the amount of luminous matter in the entire Coma cluster of galaxies, and then measured the speeds of the galaxies as they orbited the cluster. Zwicky came up with a mass-to-light ratio of about 500, implying that 99 percent of the matter in the cluster is hidden. At the moment, most astronomers dismiss such extreme numbers as astronomical flukes.



McDonald Observatory image of NGC3521. Inset shows detail in the central region (at the same scale).

SUPERNOVAE LEAVE BEHIND COSMIC X-RAY GENERATORS

Two years after discovering that the universe is awash in X-rays, astronomers are starting to pinpoint discrete sources with greater accuracy – and none of which resemble your doctor's X-ray machine.

One source is the Crab nebula, the remnant of a supernova that exploded nearly 900 years ago. Another, designated Ophiuchus XR-1, lies tantalizingly close to the site of another past supernova, SN 1604. In fact, the distribution of X-ray sources in the galaxy mimics that of the known supernova remnants, suggesting that supernovae may leave behind X-ray generators. The exact cause of the X-ray radiation is still a mystery, but if Ophiuchus XR-1 does, indeed, originate from a supernova remnant, then a comparison of these two sources may peel back some of the mystique.

The feat of narrowing down these sources should not be underestimated. Scientists had to develop improvements to astronomical X-ray instruments for rockets and then obtain enough observing time on them for sufficient measurements. Rockets are needed because X-rays cannot penetrate Earth's atmosphere. The atmosphere protects life from dangerous X-rays in space, but it also makes advancing the fledgling field of X-ray astronomy rather difficult and expensive.

The identification of these X-ray sources is the culmination of about three years of rocket flights searching for sources other than the Sun, which is weak in X-rays. The first rocket launch in 1962 used its precious five minutes in space to observe the Moon in X-rays. Riccardo Giacconi and his team at American Science and Engineering, Inc. expected to discover minerals fluorescing in X-rays as a result of being hit by heavy atomic particles from the Sun.

What they found instead was unexpected and far more amazing. A seemingly uniform X-ray hum was coming from every direction in the sky, with a particularly intense X-ray source from the direction of the constellation Scorpius. They named the new spot Scorpius X-1. Unlike the Crab nebula, however, Sco X-1 remains a celestial mystery, as it still has not been tracked to any known heavenly object.

X-ray astronomers hope someday to make their work a little easier by placing instruments in a stable, longer-term orbit that allows more observation time. Until then, the data from those five floating minutes in space is much prized for study.

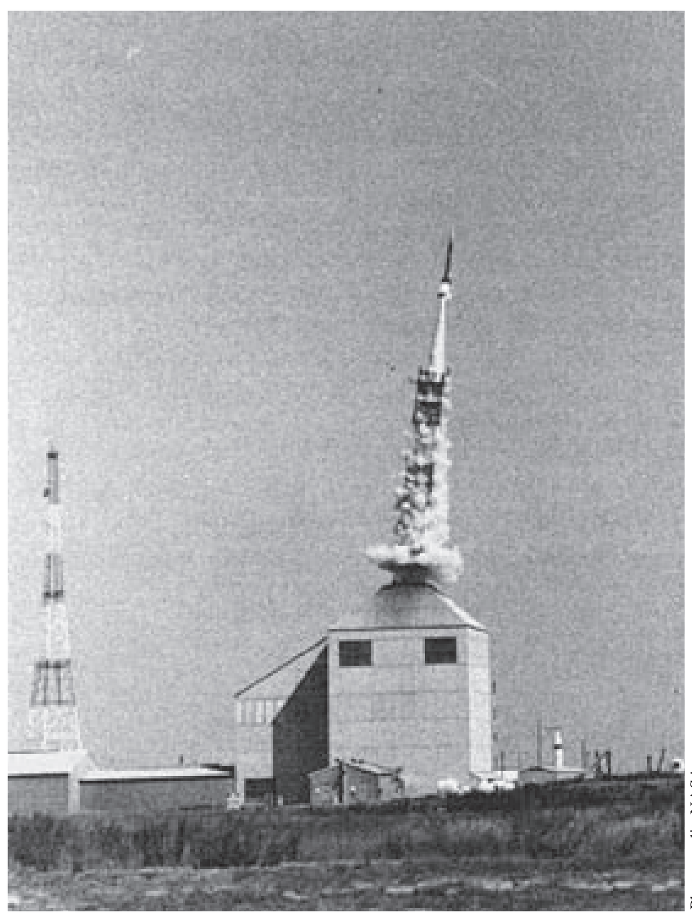


Photo credit: NASA

An Aerobee rocket launches from Wallops Island, Virginia. This rocket is similar to those used in recent discoveries of cosmic X-ray sources such as Scorpius X-1 and, more recently, the Crab nebula and Ophiuchus XR-1.

QUASARS: *Express Trains To Netherworlds*

Astronomers have discovered a quasar racing towards the edge of the known universe at the unprecedented speed of 450 million miles per hour – two-thirds of the speed of light! This and other new-found quasars have more than speed going for them, however. The fact that these strange objects are visible to us from these far distances means they must be fantastically bright.

For years, radio astronomers have seen quasi-stellar objects, or quasars, adding them to a growing list of unexplained "loud" radio sources all over the sky. In 1960, astronomers managed to match a quasar with an object seen by optical telescopes. But it was only two years ago that astronomers Jesse Greenstein and Maarten Schmidt managed to determine the speed of one.

That was when Greenstein and Schmidt split the visible light from quasar 3C 273 into its spectrum of colors. What they found was jaw dropping. The telltale pattern of spectral lines, which signify the presence of specific elements, were shifted dramatically to the red side of the spectrum, the optical equivalent of a train whistle's tone dropping as the train moves away. In the case of 3C 273, the redshift corresponded to an astonishing speed of 16 percent of the speed of light – more than 100 million miles per hour. The same technique was used by Schmidt and Caltech's Allan Sandage to clock the latest record holder, dubbed quasar BSO-1.

No one has yet explained what a quasar is, but Sandage reported, "We do know that [quasars] provide us with the long-sought keys to determine the size and shape of the universe."

Scientists are confident that at least one theory can be ruled out. Quasars are not coded messages from a super-civilization, as has been suggested by Russian astronomer Nikolai Kardashev. It is highly improbable that any civilization could broadcast messages with the power of 10,000 billion suns.

Any message from quasars may be from the universe itself. Astronomers at the 200-inch Mount Palomar telescope hope that, by measuring the distance to more quasars, they can catch sight of some that started shining when the universe was just seven percent of its current age. Some of that light, perhaps 15 billion years old, is only now reaching Earth.